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DISTANCE ESTIMATION TRAINING WITH NIGHT VISION GOGGLES UNDER LOW ILLUMINATION

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Aircrews have reported significant problems in depth perception and distance estimation with night vision goggles (NVGs). The purpose of this experiment was to examine the value of a simple training procedure as a means of reducing errors. A pre/post-test design was used in which distance estimates for a training group and control group were compared. The results revealed significant reductions in errors and variability following exposure to the training procedure. No significant reduction in errors and variability occurred with the control group. These results are consistent with a preliminary experiment using NVGs and earlier research using unaided vision. Issues for future research are also addressed.

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PREFACE

This work was conducted by the Armstrong Laboratory, Aircrew Training Research Division (AL/HRA), with support from the University of Dayton Research Institute (UDRI). Both are located in Mesa, AZ. This work was conducted under Work Units 1123-32-06, Night Vision Device Training Research, and 1123-03-85, Flying Training Research Support. UDRI, working under contract F33615-90-C-0005, supports AL/HRA by supplying night vision device (NVD) subject matter expertise in the areas of NVD research, development, test and evaluation.

This report describes an experiment that evaluated a training procedure to aid night vision goggle (NVG) operators in making distance estimates. More specifically, the study examined the effectiveness of a simple "perceptual calibration" technique in reducing estimation errors.

The authors would like to thank Capt. Scott Middleton (AL/HRA) for his help in data collection and Mr. Brady Antonio (UDRI) for his help in designing the testing apparatus. Also, thanks to Mr. Deke Joralmon (UDRI), Dr. Chuck Antonio (UDRI), and Col. William Berkley (AL/HRA) for overseeing NVG adjustment and visual acuity measurement procedures. Thanks to Ms. Marge Keslin (UDRI) for her superb editorial support and Ms. Margie McConnon for her creative graphics work. Finally, thanks to all the people who volunteered to serve as subjects in this experiment.

DISTANCE ESTIMATION TRAINING WITH NIGHT VISION GOGGLES UNDER LOW ILLUMINATION

INTRODUCTION

Distance judgment and depth perception are fundamental skills required in aviation. Unfortunately, little is known about how these skills develop, how stable they are, what asymptotic levels of performance are possible, or how much within- and between-person variability exists. This is particularly true for adults operating in large volumes of three-dimensional space. Distance estimation is not formally taught in pilot training, and rules of thumb are typically passed on from instructor to student in an informal and invalidated manner. It is assumed that these skills will develop as a natural by-product of flying activities.

Modern military aircraft have avionic suites that provide information used to aid in making judgements of distance. When data from these sources (e.g., radar altimeter, target tracking radar, laser range finder, inertial navigation) are combined with perceptual experiences of the corresponding visual array of the outside world, the pilot talks about "calibrating his eyeballs." That is, he repeatedly and somewhat systematically pairs visual percepts with valid distance data to form an internal perceptual calibration that he will rely on when circumstances do not permit him to cross-check instruments. Anecdotal evidence from pilots' self-reports suggest that this internalized perceptual yardstick tends to break down when there are substantial changes in the visual environment, particularly when the visual array is impoverished or ambiguous. Viewing the world through night vision goggles (NVGs) presents a degraded image.

Inaccurate distance estimation with NVGs has been identified as a serious problem by aircrew members (Crowley, 1991; Donohue-Perry, Hettinger, & Riegler, 1992) and has been implicated as a

factor in some rotorwing accidents (Fuson, 1990). This problem is of particular concern to helicopter crew members who often need to estimate distances from their position to an object as well as between two objects during hover and landing phases of flight. For example, they must judge whether the helicopter rotor blade will clear an obstacle or whether a landing zone (LZ) is wide enough to land safely. The crucial distances are within 150 ft, with the most important distances ranging from 40-60 ft (typical range of rotor blade lengths).

Previous Research

Distance estimation research with NVGs at distances greater than 20 ft has been very limited. Foyle and Kaiser (1991) examined the issue at distances between 20 and 200 ft with AN/AVS-6 NVGs. The results revealed that half of the subjects underestimated distances and half of the subjects overestimated distances.

The only other study addressing far distance estimation with NVGs was conducted by Wiley, Glick, Bucha, and Park (1976). They examined distance judgments with generation II NVGs (AN/PVS-5) at distances between 200 and 2,000 ft. Their results revealed that NVG distance judgments were significantly worse than unaided daylight monocular and binocular distance judgments.

Although distance estimation problems with NVGs have been acknowledged and documented, attempts to remedy the situation have been lacking. There have been attempts to improve unaided distance estimation through training. Gibson and Bergman (1954) demonstrated that corrective feedback can improve absolute distance estimation. They reported a reduction in error of 19% after training and concluded that subjects were able to associate changes in perspective and texture gradient distance cues with changes in distance.

In a follow-on study, Gibson, Bergman, and Purdy (1955) examined distance estimation training to determine whether improvements brought about through training will transfer to a new location. An experimental group was trained via a method of fractionization and was given a scale of measurement to aid in making judgements. A control group was given no scale. The experimental and control groups were then tested on absolute distance estimation in an area different than that of the training. The results revealed that the training group performed better in both absolute error and estimation variability than the control group.

The Present Experiment

The results of the Gibson et al. (1954; 1955) studies prompted us to use a similar methodology. However, in the present experiment, distance estimates were made between object-to-object (exocentric) distances and between person-to-object (egocentric) distances while wearing NVGs. The training technique used a perceptual calibration procedure that involved having subjects examine the targets at known distances. This procedure was chosen, in part, because it could be easily implemented at most locations at a low cost. Furthermore, a preliminary study (Reising & Martin, in press) showed it to be effective in reducing errors and variability.

Under starlight illumination conditions, NVGs produce an image that contains high noise (scintillation), which degrades the NVG image and decreases the amount of monocular distance cues available. The present experiment restricted testing to nights of starlight illumination only.

METHOD

Apparatus

Test Area. The testing was conducted in a large field containing dirt, grass, and very small shrubs. The primary

distance cues available to the subjects were gradients of texture density, binocular disparity, and motion parallax. A few trees were visible about 300 yds in front of the test area. Some cultural lights were visible in the distance. None were located within 3 mi of the direction of gaze of the test area, and most were more than 15 mi away. Dispersed about the area were 13 targets consisting of numbered white isosceles triangles, 40 in. high and 27 in. across the base. The targets had a reflectance of 70.12% and the numbers on the targets had a reflectance of 17.30%. The test area, depicted in Figure 1, was set up so that one target would be positioned within each 10 ft interval from 20 to 140 ft from the subject. Thus, there were 12 subject-to-target (egocentric) distances. Target positioning also was constrained so that each egocentric distance would have an equivalent [+/- 3 ft] target-to-target (exocentric) distance; an extra target was used to fulfill this positioning constraint. Therefore, the total number of distances being judged was 24. Table 1 presents the target numbers making up the 12 egocentric and 12 exocentric distances. Figure 1 depicts the test area (subjects viewed the area from the position "s").

Table 1. The Target Numbers Comprising the Egocentric and Exocentric Distances During Testing.

EGOCENTRIC		EXOCENTRIC	
TARGETS	DISTANCE (ft)	TARGETS	DISTANCE (ft)
(S,1)	135	(3,10)	135
(S,4)	125	(3,11)	123
(S,7)	112	(2,1)	114
(S,8)	105	(2,11)	105
(S,2)	95	(4,11)	95
(S,11)	85	(13,1)	82
(S,9)	77	(1,9)	75
(S,5)	65	(11,7)	67
(S,13)	56	(9,6)	53
(S,10)	46	(13,11)	45
(S,12)	34	(11,5)	32
(S,6)	28	(13,9)	25

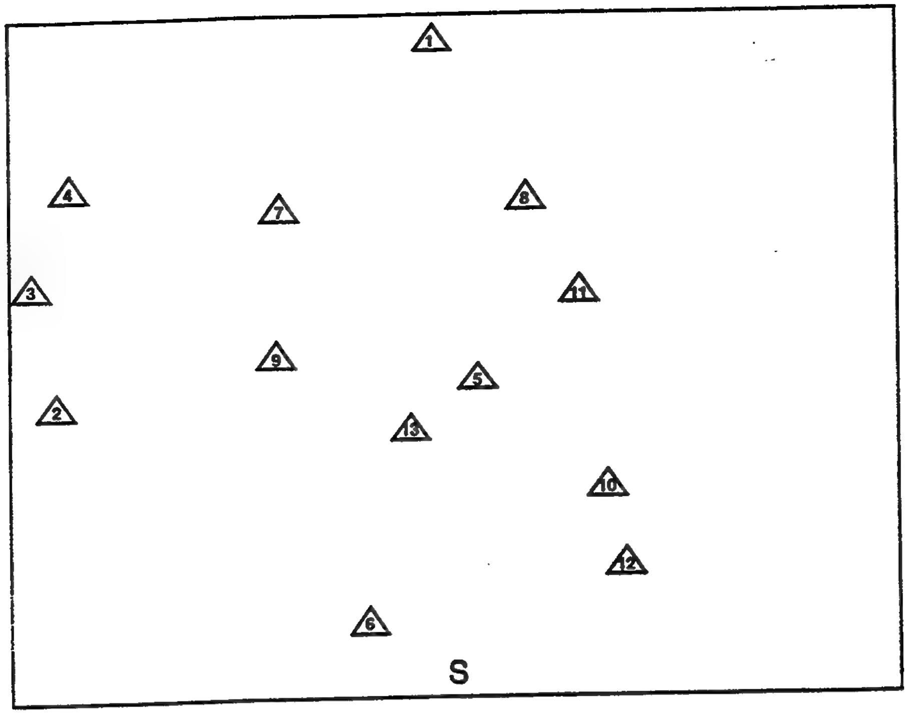

Figure 1

Representation of the Pre/Post-Test Area.

Training Area. The training area, depicted in Figure 2, was stationed away from, but in the same field as the test area. Eleven targets similar to the ones used in test were placed at known distances from the subject. Next to targets 1 through 7 were signs indicating the exact distance between a subject and that target when standing directly in front of it. The signs marked off 20 ft increments from 20 to 140 ft and were positioned 40 ft apart, diagonally across the subject's field of view (FOV). The subject viewed the targets from an observation area perpendicular to each sign (positions "A-G"). Four targets were dispersed near the area of the seven other targets to create exocentric distances (targets 8 through 11). The training distances consisted of a total of 42 (21 egocentric and 21 exocentric) and are presented in Table 2 according to viewing location. There was an equivalent number of egocentric and exocentric distances and all 10 ft distances from 20-140 ft were reviewed by the subject. Some exocentric distances

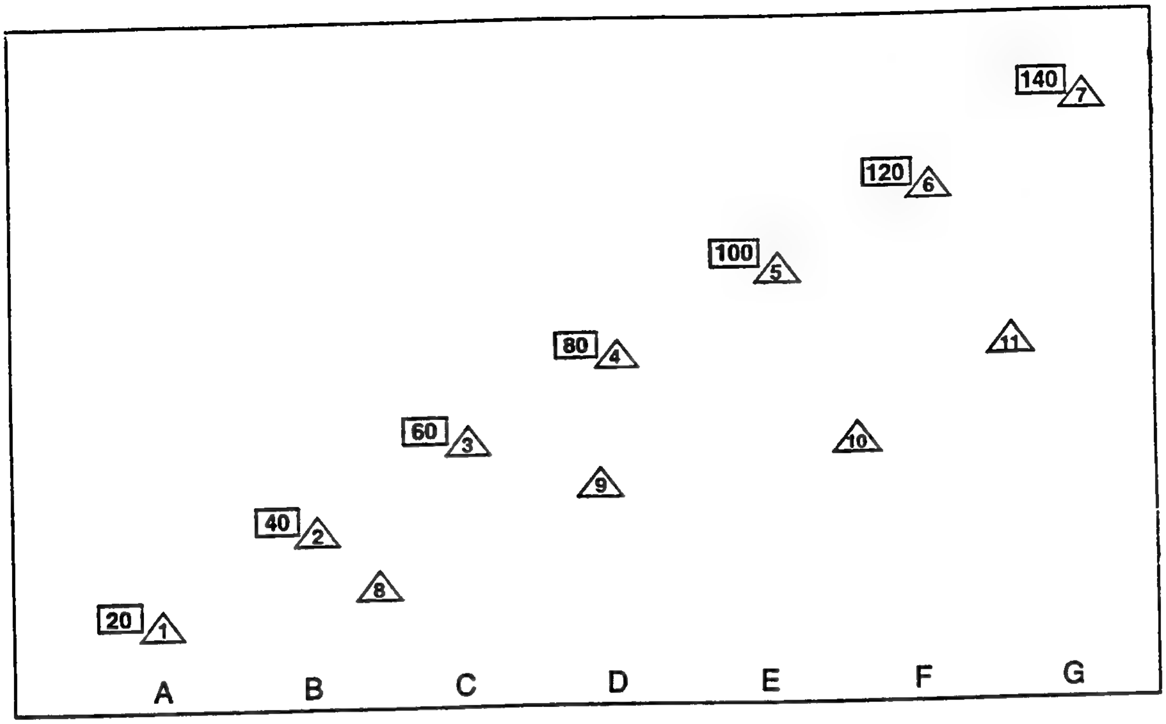

Figure 2

Representation of the Training Area.

were reviewed more often than other distances. For example, subjects were reminded at each observation position that targets 1 through 7 were consecutively spaced 40 ft apart.

__Subjects__

Twenty male subjects (ten military pilots from the U.S. Air Force and ten nonaviators) volunteered for the experiment. Age ranged from 24 to 46 years, with a mean of 33.3 years. Flight experience for the aviators ranged from 130 to 4,000 hrs, with a mean of 1,899 hrs. One aviator was a rotor-wing pilot with 80 hrs of NVG experience with AN/AVS-6 NVGs. All the other aviators were fixed-wing pilots and only one had NVG experience (150 hrs with AN/AVS-6 NVGs). The subjects all had 20/20 vision or better

Table 2. Target Numbers Comprising the Egocentric and Exocentric Distances During Training According to Viewing Location.

	EGOCENTRIC		EXOCENTRIC	
VIEWING LOCATION	TARGETS	DISTANCE (ft)	TARGETS	DISTANCE (ft)
A	(S,1)	20	(1,2)	40
A	(S,8)	55	(8,3)	38
A	(S,3)	92	(1,8)	48
B	(S,2)	40	(2,3)	40
B	(S,1)	42	(2,8)	17
B	(S,8)	31	(3,9)	27
C	(S,3)	60	(3,4)	40
C	(S,4)	85	(8,9)	53
C	(S,8)	36	(8,4)	75
D	(S,4)	80	(4,5)	40
D	(S,1)	106	(8,10)	109
D	(S,9)	50	(9,5)	65
E	(S,5)	100	(5,6)	40
E	(S,2)	112	(8,5)	115
E	(S,10)	65	(4,11)	88
F	(S,6)	120	(6,7)	40
F	(S,8)	132	(3,11)	125
F	(S,10)	68	(10,7)	97
G	(S,7)	140	(6,7)	40
G	(S,4)	122	(9,7)	146
G	(S,10)	80	(10,11)	45

(including corrections) and could achieve at least 20/35 visual acuity with NVGs as tested in an NVG eyelane with a standard NVG resolution chart.

Experimental Design

The study employed a 2 x 2 x 2 mixed factorial design. The independent variables consisted of TEST (pre-test, post-test), DISTANCE TYPE (egocentric, exocentric), and GROUP (training, control). The dependent variables consisted of both absolute and relative absolute judgment error and standard deviation of the absolute judgment error. Absolute error was computed by first averaging a subject's two estimates for each distance and then taking the absolute error of a subject's judgement minus the actual distance. A single absolute error score was obtained for each

condition by collapsing across distance. Relative absolute error was computed by dividing each absolute error score by the actual distance and then collapsing across distance. Standard deviation of the absolute error was the average variation of a subject's absolute error score from the group mean for each condition.

Procedure

Subjects were first taken to an NVG eye lane where NVGs and helmets were fitted and adjusted, and NVG visual acuity was measured. The eye lane consists of a light-tight room with an NVG resolution chart that is illuminated to full moon conditions. Subjects adjust NVGs by viewing the resolution chart and focusing the NVGs to obtain the best visual acuity possible. An experimenter was present to assist the subjects with the NVG adjustments. After NVG adjustment, subjects were transported to the testing area. Subjects gave distance estimates twice for each of the 24 intervals. The order of distance presentation was randomized for all sequences. After pre-testing, subjects were taken to the training area where they were told the nature of the training setup, including the spacing of the targets in the field. Subjects were then positioned in front of each sign and were told specific egocentric and exocentric distances. For example, at position A (see Fig. 2) subjects were told that the distance between them and target 1 was 20 ft, between them and target 8 was 55 ft, between them and target 3 was 92 ft, between targets 1 and 8 was 48 ft, and between targets 8 and 3 was 38 ft. They were also reminded that targets 1 and 2 were 40 ft apart. The subjects then moved to position B and were given six more distances to examine. Subjects were told to study the distance intervals in order to "calibrate their eyes" to the NVG display. The training lasted for approximately 10 min. Subjects were then taken back to the test area for a post-test evaluation. The same distances used in the pre-test evaluation were judged by the subjects. Testing and training were conducted under starlight conditions. The night vision imaging system radiance (NR) from a target measured during

one of the testing nights was 4.5×10^{-10} NRA.

RESULTS

The results were analyzed in terms of experience, regression, error, and subject variability. As mentioned previously, the egocentric and exocentric distance types were not exactly equal (some differed by as much as 3 ft). The measures computed during statistical analysis were based upon the exact distance for the two distance types. However, for presentation purposes the ego- and exocentric distances were treated as if they were equivalent.

Experience

Because the subjects consisted of a mixture of aviators and nonaviators, an analysis was conducted on the pre-test absolute error data to determine if the two EXPERIENCE groups differed on either DISTANCE TYPE (egocentric, exocentric). A 2 x 2 Analysis of Variance (ANOVA) revealed no significant differences between aviators and nonaviators on the pre-test. The results of the analysis are displayed in Table 3. With no difference among the groups, the remainder of the statistical analysis were collapsed across EXPERIENCE.

Table 3. Experience ANOVA Summary Table.

Source	Degrees of freedom	Sum of squares	F Value	p
EXPERIENCE	1	53.91	0.36	0.557
DISTANCE TYPE	1	24.89	0.17	0.689
EXPERIENCE x TYPE	1	22.22	0.15	0.706
ERROR	15	2249.25		

Regression Analysis

To provide an indication of the relationship between actual distance and estimated distance, a regression analysis was conducted. The regression equations were developed based upon the results of an Analysis of Covariance (ANCOVA) with ACTUAL DISTANCE as the covariate. The ANCOVA revealed that the ACTUAL DISTANCE X DISTANCE TYPE interaction was significant [$F(1,80) = 39.35$, $p < .001$], with exocentric slopes significantly greater than egocentric slopes. No effects with the TEST variable were significant in the ANCOVA results and thus, the regression equations are collapsed across TEST. The regression equations, plotted in Figure 3, present mean estimated distance as a function of actual distance for both the egocentric and exocentric conditions. The heavy solid line in Figure 3 represents optimum scores with a slope equal to one and a Y intercept equal to zero. As can be seen, the individual data points fall in a linear pattern, with perceived distance increasing with actual distance. The regression equations developed for the egocentric and exocentric conditions respectively are the following:

Egocentric Estimated Distance = -0.460 + 0.812 (Actual Distance)
Exocentric Estimated Distance = -6.459 + 1.114 (Actual Distance).

The goodness of fit of these equations is confirmed by the large coefficients of determination, r^2, for each condition; egocentric = 0.993 and exocentric = 0.944. In addition, further examination of Figure 3 reveals that subjects tended to underestimate distance for all egocentric intervals. This trend accurately represents the individual data as well. Based upon a 75% criterion to classify distance estimation bias, 14 of 20 subjects were classified as egocentric underestimators, 2 were classified as overestimators, and the remaining 4 showed no clear bias. For exocentric distances, 7 of 20 could be classified as underestimators, 5 were classified as overestimators, and 8 showed no clear bias. It should be noted that the egocentric slope

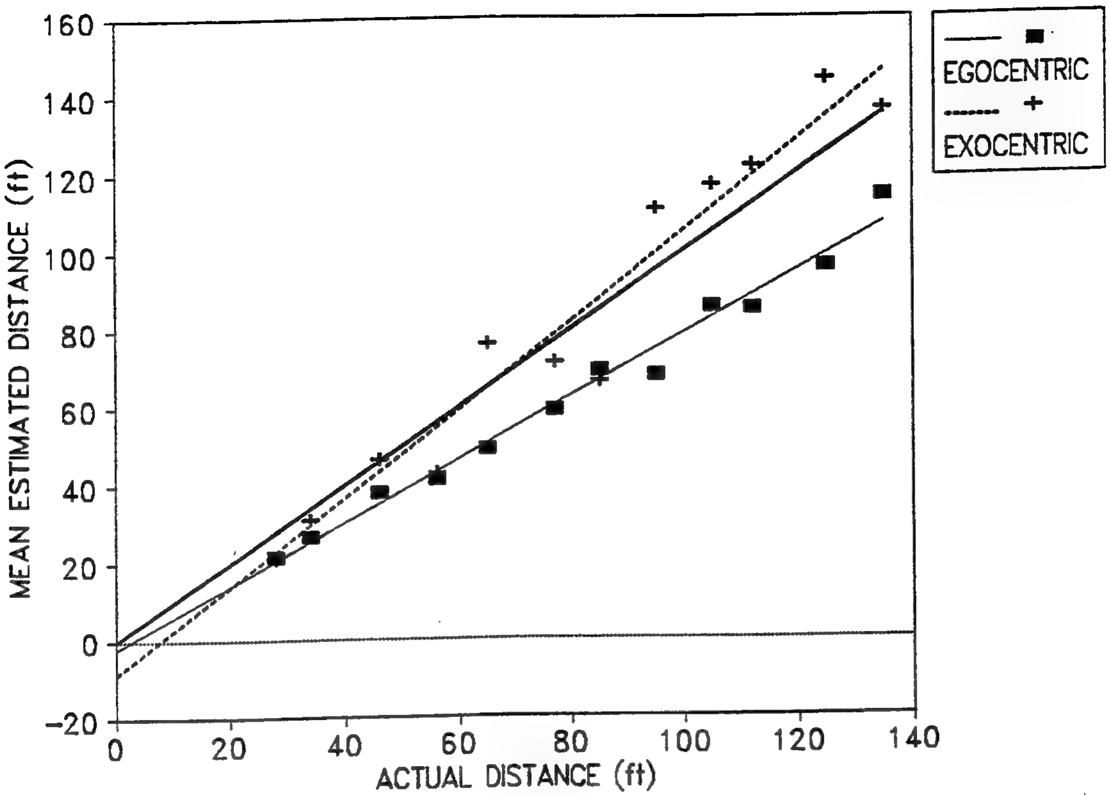

Figure 3
Regression Plots for the DISTANCE TYPE Condition
as a Function of Estimated and Actual Distance

(SE = 0.021) is significantly less than 1 [$t(10) = -8.94$, $p < 0.01$] whereas the exocentric slope (SE = 0.086) is not significantly greater than 1.

Mean Absolute Error

The primary interest in this experiment was to determine if estimation error decreased after training. In addition, it was of interest to examine differences between egocentric and exocentric distance judgments, and to see if training differentially affected one type of distance judgment. A 2 x 2 x 2 mixed ANOVA was conducted on the absolute error data. Table 4 presents the results of the ANOVA, revealing a main effect of TEST [$F(1,54) = 9.42$, p =

Table 4. Mean Absolute Error ANOVA Summary Table.

Source	Degrees of freedom	Sum of squares	F Value	p
TEST	1	982.33	9.42	0.003
DISTANCE TYPE	1	26.55	0.25	0.616
GROUP	1	769.83	7.38	0.009
TEST x TYPE	1	3.94	0.04	0.847
GRP x TYPE	1	0.69	0.01	0.936
GRP x TEST	1	660.29	6.33	0.015
GRP x TEST x TYPE	1	1.63	0.02	0.901
ERROR	54	5633.71		

0.003] and a main effect of GROUP [$F(1,54) = 7.38$, $p = 0.009$]. The GROUP x TEST interaction was also significant [$F(1,54) = 6.33$, $p = 0.015$]. No other effects were significant.

Figure 4 presents a plot of the means for the TEST x GROUP interaction. As can be seen, mean absolute error decreases during post-testing for the training group but not for the control group. The effect of training can be examined further in Figure 5. This graph plots the mean absolute error (collapsing across distance type) as a function of each distance for the training group only, and shows that most of the error occurs at the longer distances. There is also a decrease in error after training for all the distances.

Relative Absolute Error

Relative absolute error was computed to equalize the magnitude of error across the various distances. As was the case with absolute error, a 2 x 2 x 2 mixed ANOVA was conducted on the data. The results parallel the absolute error data with significant main effects of TEST [$F(1,54) = 9.33$, $p < 0.004$] and GROUP [$F(1,54) = 6.70$, $p < 0.012$], and a significant GROUP x TEST interaction [$F(1,54) = 6.91$, $p < 0.011$]. The interaction results are depicted in Figure 6 and show a decrease in relative absolute error during

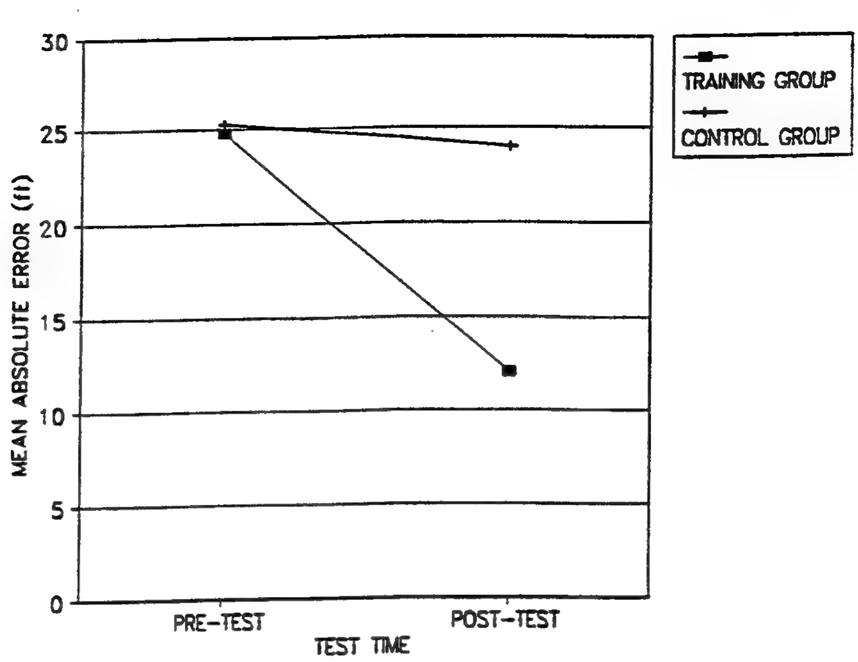

Figure 4
Mean Absolute Error as a Function of TEST and GROUP

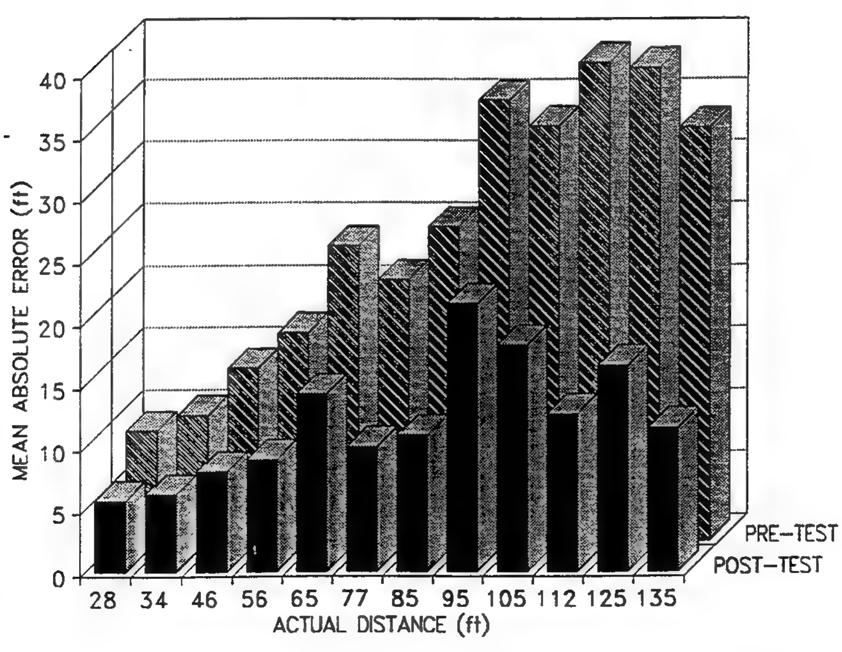

Figure 5
Training Group Mean Absolute Error as a Function
of TEST and Actual Distance

post-testing for the training group from 31% to 15%. However, no significant drop is present with the control group.

Standard Deviation of the Absolute Error

Another measure of the effect of training is subject variability. The standard deviation of the absolute error was analyzed by a 2 x 2 x 2 mixed ANOVA. The results are displayed in Table 5. The analysis revealed that the main effects of TEST and GROUP were significant with [$F(1,54) = 5.80$, $p < 0.019$] and [$F(1,54) = 5.49$, $p < 0.023$], respectively. In addition, the GROUP x TEST interaction was significant [$F(1,54) = 4.33$, $p < 0.042$]. The mean standard deviations for the group are displayed in Figure 7. As can be seen, subject variability decreases during post-testing for the training group but not for the control group. Figure 8 displays the training group's subject variability at each distance and reveals that variability decreases after training at all distances. There is a tendency for variability to be higher at longer distances than shorter ones during both pre- and post-testing.

DISCUSSION

The results of the regression analysis revealed two important aspects of NVG distance estimation: linearity of the data and direction of estimation bias. Distance judgments appear to be nearly linear as indicated by large coefficients of determination. This finding is also consistent with the results of a pilot study (Reising & Martin, in press). Previous research with unaided vision in natural outdoor settings (e.g., Gibson & Bergman, 1954; Gibson, Bergman, & Purdy, 1955; Gilinsky, 1951; Teghtsoonian & Teghtsoonian, 1970) describes distance estimation with typical psychophysical power functions, requiring a log transform of either the estimate and/or the actual distance. Data from this experiment did not require a log transform in order to achieve a linear relationship. The significance of this difference at this point is

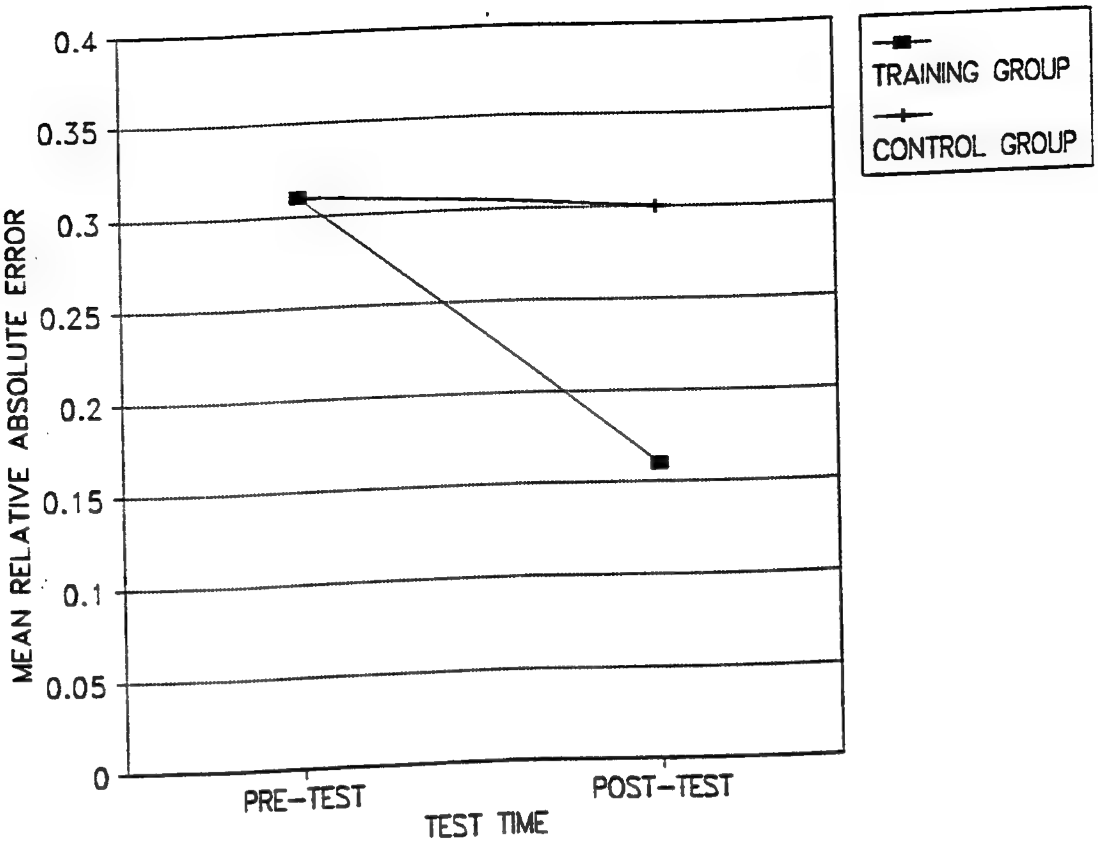

Figure 6
Mean Relative Absolute Error as a Function of TEST and GROUP

Table 5. Standard Deviation of the Absolute Error ANOVA Summary Table

Source	Degrees of freedom	Sum of squares	F Value	p
TEST	1	269.68	5.80	0.023
DISTANCE TYPE	1	184.17	3.96	0.052
GROUP	1	255.03	5.49	0.023
TEST x TYPE	1	11.35	0.24	0.623
GRP x TYPE	1	3.93	0.08	0.772
GRP x TEST	1	201.16	4.33	0.042
GRP x TEST x TYPE	1	3.18	0.07	0.795
ERROR	54	2510.71		

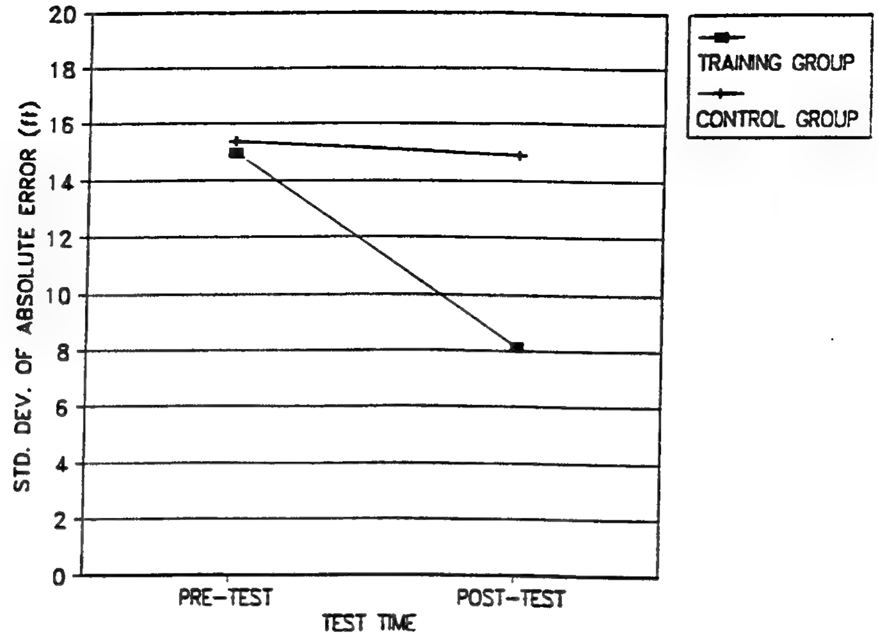

Figure 7
Standard Deviation of the Absolute Error
as a Function of TEST and GROUP

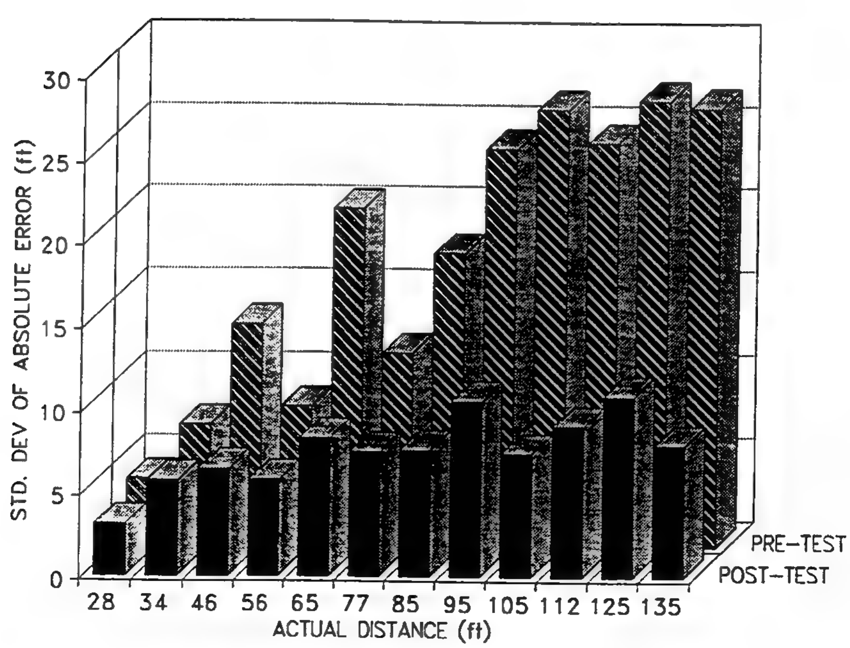

Figure 8
Training Group Standard Deviation of the Absolute Error
as a Function of TEST and Actual Distance

not known and could be due to a number of methodological factors. However, it could reflect a more fundamental difference due to the characteristics of NVGs.

The second point to be mentioned about the regression analysis is the apparent tendency to underestimate the egocentric distances and to be more accurate with exocentric distances. This finding is interesting to the extent that it reflects the performance of the individual subjects. In fact, 14 of the 20 subjects could be classified as egocentric underestimators, 2 as overestimators, and 4 had no consistent bias. Recall that Foyle and Kaiser (1991) found that 2 subjects overestimated and 2 underestimated distance. It seems that some individuals may exhibit a clear bias but that it is by no means always in the same direction. From a purely practical standpoint, the tendency to underestimate is not as dangerous as the reverse.

The fact that more accurate estimates are associated with exocentric distances is surprising since all subjects reported that the exocentric judgments were more difficult. In addition, a few of the exocentric judgments required extensive scanning due to the wide angular separations of the targets. Levin and Haber (1993) have recently demonstrated that when the actual distances are held constant, the angular separation becomes a significant factor in judging distances, leading to overestimation as the angle increases. Since the experimental setup for this experiment did not attempt to control for this factor, no conclusions can be drawn regarding the role of angular separation between the targets. However, according to Levin and Haber, all exocentric distances will be overestimated when compared to equivalent egocentric distances. This may partially explain why exocentric judgments were not underestimated like their counterpart egocentric distances. Furthermore, it may be that the increased scanning associated with exocentric distances enhances the motion parallax distance cue in a manner that overcomes an underestimation bias

associated with NVGs in this experiment. Elucidation of this pattern will require additional research.

Our primary interest in this experiment was to determine if training decreased estimation errors. Results of the analysis showed that there was a significant decrease (48% reduction) in absolute error after training. However, as Figure 5 reveals, error is still as high as 8 ft at the critical distances (40-60 ft). The fact that a consistent increase from 34 to 46 to 56 ft distances is present, indicates that the emphasis placed upon the 40 ft distance during training was not beneficial. The analysis also revealed that training was equally effective for both egocentric and exocentric distances.

A major focus of this experiment was to assess the effectiveness of a simple calibration procedure as a means of training distance estimation with NVGs. In that context, the emphasis is on absolute error. However, it is also of value to discuss the use of relative absolute error as a dependent measure. The results of the relative absolute error analysis revealed a decrease from 31% to 16% after training. Although the decrease was significant, it should be noted that the error was high. Foyle and Kaiser (1991) obtained a relative absolute error of roughly 20% with AN/AVS-6 NVGs. The fact that the error obtained in their study is 11% lower may be due to the experience of their subjects. All of their subjects were helicopter pilots with NVG experience. Only two subjects used in this experiment had NVG experience and most were fixed wing pilots.

Almost as important as the reduction in error is the reduction in variability between subjects' estimates that occurs after training. One desirable outcome of any training program would be to develop uniformity as well as accuracy in judgments. For example, if distance estimates are more uniform among subjects, error is less likely to occur when communicating location

information. Communication of distance is a primary task in rotorwing operations because a pilot often relies upon verbal feedback from both the side and tail scanner crew members for position information. Subject variability in the amount of distance estimation absolute error was shown to significantly decrease after training. Thus, subjects' perception of distance became more uniform. However, subjects still vary as much as 6 ft on the critical distances (40-60 ft) after training.

CONCLUSION

This experiment revealed that a simple calibration training procedure produced a significant reduction in distance estimation errors and variability. These results are consistent with previous research using similar procedures with unaided vision. However, there are a number of issues about the training that remain to be addressed. Are there more effective techniques that can be employed within the constraints of the operational environment? How accurate can people get with additional training? How accurate do they need to be? How long will this skill last? Will static ground-level skill transfer to dynamic in-flight situations? Will skill transfer to other illumination (i.e., moon phase) conditions? Is there a systematic relationship between one's ability to judge distance during day unaided conditions and judgments obtained using NVGs? Can people estimate distances better with more advanced NVGs? These and other issues will be addressed in future research.

REFERENCES

Crowley, J.S. (1991). Human factors of night vision devices: anecdotes from the field concerning visual illusions and other effects. (USAARL Report No. 91-15). Ft. Rucker, AL: U.S. Army Aeromedical Research Laboratory.

Donohue-Perry, M.M., Hettinger, L.J., & Riegler, J.T. (1992). Night Vision Goggle (NVG) User's Concerns Survey Site Report: Hurlburt Field, FL (U). (AL-TR-1992-0089). WPAFB, OH: Armstrong Laboratory.

Foyle, D.C. & Kaiser, M.K. (1991). Pilot distance estimation with unaided vision, night-vision goggles, and infrared imagery. SID International Symposium Digest of Technical Papers, XXII, 314-317.

Fuson, J. (1990). Crew error in night rotary wing accidents. Flightfax, 19, 1-5. U.S. Army Safety Center.

Gibson, E.J. & Bergman, R. (1954). The effect of training on absolute estimation of distance over the ground. Journal of Experimental Psychology, 48, 473-482.

Gibson, E.J., Bergman, R., & Purdy, J. (1955). The effect of prior training with a scale of distance on absolute and relative judgements over ground. Journal of Experimental Psychology, 50, 97-105.

Gilinsky, A.S. (1951). Perceived size and distance in visual space. Psychological Review, 58, 460-482.

Levin, C.A., & Haber, R.N. (1993). Visual angle as a determinant of perceived interobject distance. Perception & Psychophysics, 54.

Reising, J.D., & Martin, E.L. (In press). Distance estimation training with night vision goggles: A preliminary study. (AL/HRA-TR-1994-xxxx). Mesa, AZ: Armstrong Laboratory, Aircrew Training Research Division.

Teghtsoonian, R., & Teghtsoonian, M. (1970). Scaling apparent distance in a natural outdoor setting. Psychonomic Science, 21.

Wiley, R.W., Glick, D.D., Bucha, C.T., & Park, C.K. (1076). Depth perception with the AN/PVS-5 night vision goggles. (USAARL Report No. 76-25). Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory.